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# **Development of a Minimum Performance Standard for Hand-Held Fire Extinguishers as a Replacement for Halon 1211 on Civilian Transport Category Aircraft**

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16. Abstract  One or more Halon 1211 hand-held fire extinguishers are specified in Federal Aviation Regulation (FAR) Part 25.851 as a requirement on transport category aircraft with 31 or more seats. Halon 1211 has been linked to the destruction of the ozone layer and production of new Halon 1211 has been halted per the Montreal Protocol in 1993. The phase out of Halon 1211, as the hand-held firefighting agent of choice, for civilian transport category aircraft has necessitated the development of a Minimum Performance Standard (MPS) to evaluate replacement agents. The purpose of the MPS is to insure that there is no reduction in safety, both in terms of effectiveness in fighting onboard fires and toxicity to the passengers and crew.			
The MPS specifies two new tests that replacement agents must pass in addition to requiring national certifications such as provided by Underwriters Laboratories. The first test evaluates the "flooding" characteristics of the agent against a hidden in-flight fire. This test determines the ability of a streaming agent to function as a flooding agent. The second test evaluates the performance of the agent in fighting a terrorist fire scenario and the associated toxicity hazard. This test measures the agent's ability to extinguish a triple-seat fire in an aircraft cabin under in-flight conditions and the toxicity characteristics of both the neat agent and the products of decomposition.			
This MPS will insure that the replacement agents will meet or exceed the performance of Halon 1211 both in fighting fires and maintaining a safe breathing environment in aircraft cabins.			
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## EXECUTIVE SUMMARY

A standard was developed to certify alternate fire-extinguishing agents to replace Halon 1211 in hand-held fire extinguishers on transport category aircraft. The standard insures that there is no loss in safety for the passengers and crew due to extinguisher performance or increase in toxic byproducts due to using alternate agents. The standard consists of two tests: (1) the seat fire toxicity test was developed to screen potential alternate agents for firefighting effectiveness and potential hazard due to toxic gas byproducts resulting from extinguishing an in-flight fire; (2) the hidden fire test was developed to assess the flooding capability of the replacement agents, which should maintain the performance of the existing Halon 1211 extinguishers.

Seven agents were determined to be acceptable alternate agents as tested in the seat fire toxicity tests. These were DuPont FE-36, DuPont FE-36/FE-13, American Pacific Halotron 1, POWSUS Envirogel with phosphate, POWSUS Envirogel with bicarbonate powder, Great Lakes Chemical FM-200, and North American Fire Guardian P IV.

The hidden fire test is a hardware-specific test. Each extinguisher model must pass this test, when charged with one of the above agents, to be certified as a Halon 1211 replacement on transport category aircraft. The hidden fire test is currently being offered by Underwriters Laboratory in the United States.

## 1. INTRODUCTION.

The purpose of this standard is to provide a method to evaluate the performance of replacement hand-held fire extinguishers for Halon 1211 required on transport category aircraft. Currently, regulations require that Halon 1211, or equivalent, hand-held fire extinguishers be carried in the passenger cabin of transport aircraft. The regulation states that the type and quantity of agent, if other than Halon 1211, must be appropriate for the kind of fires likely to occur where used.

The requirement for Halon 1211 had its origin with enhancing in-flight firefighting capability, including the need to deal with the hijacking/arsonist threat which was prevalent in the late 1970s. Testing performed at the Federal Aviation Administration (FAA) William J. Hughes Technical Center identified Halon 1211 as a superior extinguishing agent for the hijacking/arsonist scenario when compared to the CO<sub>2</sub> and dry chemical extinguishers then commonly in use [1]. Later, it was determined that Halon 1211 in hand-held fire extinguishers, while primarily a streaming agent, provided the capacity to act as a flooding agent. This was demonstrated on an in-flight cheek area fire in a large transport aircraft, possibly preventing the loss of the aircraft.

The 1987 Montreal Protocol, an international treaty, was established to control the release of substances that damage the stratospheric ozone layer. As a result, the production of Halon 1211, 1301, and 2402 firefighting agents was phased out in all industrialized countries in 1993. Halon 1211 is still available from stockpiled and recycled sources but will be phased out when a suitable replacement is developed. This standard describes the tests required to show that the performance of the replacement agents equals or exceeds the performance of the current Halon 1211 fire extinguishers.

The tests described in this standard are one part of the total FAA certification process. Compliance with other applicable regulations, some of which are listed below, is also required. Applicants attempting to certify replacement fire extinguishers are encouraged to discuss the required process with regulatory agencies prior to conducting testing.

## 2. DEVELOPMENT OF THE MINIMUM PERFORMANCE STANDARD FOR HAND-HELD FIRE EXTINGUISHERS.

### 2.1 SCOPE.

The Minimum Performance Standard (MPS) seeks to insure that there is no loss of safety to the flying public by the removal of Halon 1211. All replacement extinguishers must meet the certification requirements of a national listing organization, such as Underwriters Laboratory standard UL 711 or the British standard BS 3A:34B. This insures a firefighting capability equal to a UL 5BC-rated, 2.5-lb. Halon 1211 fire extinguisher. In addition, the agent must demonstrate that it is acceptable in two additional tests that are specific to aircraft use described in this MPS.

- a. Hidden Fire Test. The extinguisher must be able to extinguish fires in indirectly accessible spaces (hidden fires) as effectively as the currently required Halon 1211 2.5-lb., UL 5BC-rated extinguisher. Hand-held extinguishers are by nature streaming agents. Halon 1211 has the ability to also function as a flooding agent. To insure no loss

of safety, replacement agents must maintain this ability. A hidden fire test has been developed to assess the firefighting performance of the hand-held extinguisher/agent combination in a flooding scenario.

b. Seat Fire/Toxicity Test. The extinguisher must have an acceptable toxicity for use where people are present. In particular, the combined toxicity of the agent and fire products must not be unacceptable for use in an aircraft cabin under in-flight conditions. A test has been developed to measure the toxicity of the agent and its products of decomposition when extinguishing a seat fire in an aircraft cabin.

## 2.2 APPLICABLE REGULATIONS.

The following existing Federal Aviation Regulations (FARs) pertain to hand-held portable extinguishers as required for transport aircraft:

Airworthiness Standards:

Transport Category Airplanes, FAR Part 25.851

Normal, Utility, Acrobatic, and Commuter Airplanes, FAR Part 23.851

Transport Category Rotorcraft, FAR Part 29.851

Operating Requirements:

Domestic, Flag, and Supplemental Operations, FAR Part 121.155

Commuter and On-Demand Operations, FAR Part 135.155

FAR Part 25.851 specifically requires that one or more Halon 1211 fire extinguishers be carried on air transport category aircraft with more than 31 passenger seats.

## 2.3 AGENT SELECTION GUIDELINES.

a. Fire Type. The agent must be suitable for fighting materials fires typical of those encountered on commuter and transport aircraft cabins, lavatories, accessible baggage compartments, and flight decks. In hand-held configuration, the agent must exhibit streaming as well as some flooding characteristics.

b. Environmental Concerns. Airworthiness requirements specifically call for Halon 1211 or equivalent portable fire extinguishers for in-flight firefighting. Halon 1211 has been identified as one of a number of chemicals responsible for depletion of the ozone layer. Under the provisions of the Montreal Protocol, production of Halon 1211 has effectively been halted. Any new agents considered as a replacement for Halon 1211 must be environmentally friendly. The environmental characteristics of a replacement agent that need to be addressed are ozone depletion potential (ODP), global warming potential (GWP), and atmospheric lifetime. This performance standard addresses only the firefighting effectiveness of the agent.

- c. Toxicology. The replacement agent must not create a toxic hazard when discharged in an aircraft cabin.
- d. Extinguisher Rating. The candidate extinguisher must be approved by a recognized fire testing laboratory and have a minimum rating of UL 5BC or an equivalent rating to 2.5 pounds of Halon 1211.

#### 2.4 PERFORMANCE TESTS.

- a. Hidden Fire Test. (see appendix A, paragraph A.1)

The hand-held hidden fire test is designed to determine the performance of the agent/extinguisher in a flooding scenario. The test is comprised of 20 n-Heptane cup fires in a three-dimensional (3-D) array separated by perforated baffles. The cup fires are allowed to burn for 30 seconds before the extinguisher is discharged from a fixed location on the left side of the apparatus. The number of fires extinguished is tallied. Baseline testing with Halon 1211 resulted in nine fires extinguished.

- b. Seat Fire/Toxicology Test. (see appendix A, paragraph A.2)

The seat fire/toxicology test is designed to evaluate the type and concentrations of toxic gases formed when the agent is used to extinguish a typical seat fire under airflow conditions normally found in an aircraft cabin. The test will be performed in the "TC-10" test article at the FAA William J. Hughes Technical Center. The test conditions include a triple aircraft seat that has been fire blocked. The seat is primed with 1 quart of gasoline and ignited. The fire is allowed to burn for 30 seconds before being extinguished. Instrumentation is provided to measure the products of decomposition, CO, CO<sub>2</sub> and appropriate acid gases (HF, HCl, etc.), O<sub>2</sub>, and the concentration of the neat agent in the cabin. Baseline testing was performed with Halon 1211 to determine acceptable levels of exposure.

#### 2.5 DEVELOPMENT OF THE HIDDEN FIRE TEST.

Hand-held fire extinguishers charged with Halon 1211 are required equipment on commercial transport aircraft. This requirement is traced to work performed at the FAA William J. Hughes Technical Center by Hill, et al. [1]. It was determined by Hill that the performance of Halon 1211 dramatically exceeded CO<sub>2</sub> and dry chemical extinguishers in protecting against fuel fed seat fires. This threat is derived from the hijacking/arsonist scenario that was prevalent in the late 1970s.

Halon 1211, though a streaming agent, can also perform remarkably well as a total-flood agent. This enables flight attendants to fight fires that are inaccessible from the cabin but extinguishable using the agent's total-flood capability. This total-flood capability is not measured by the standard Underwriters Laboratory tests that yield a UL 5BC rating. Therefore, a new test had to be developed.

The hand-held extinguisher total-flood test was developed by Kidde International Research, Colnbrook, England, under contract to the Civilian Aviation Authority Safety Regulation Group. The basic design of the test fixture is described in a report by A. Chattaway [2].

The FAA has used the design for the test fixture developed by Chattaway (figure 1); however, a modified test procedure is employed to evaluate the flooding characteristics of a candidate extinguisher. It was determined that the effectiveness of the agent was affected by the hardware used to deliver it. Therefore, a blanket approval will not be issued for a given agent. Approval will be granted on an agent/hardware unit only.



FIGURE 1. HIDDEN FIRE TEST APPARATUS

#### 2.5.1 Standardization of the Hidden Fire Test Procedure.

A test procedure was developed to insure that the test results would be repeatable and minimize the effects of operator error and environmental influences. Tests were run with Halon 1211 as the extinguishing agent to determine the effects of nozzle orientation, preburn time, and interior box temperature.

##### 2.5.1.1 Effect of Preburn Time on Agent Performance.

The FAA test procedure differs from the procedure developed by Chattaway in that all 20 cup fires are ignited. The Chattaway procedure uses eight cup fires per test and runs a matrix of four to six tests to evaluate the extinguisher's performance. It was determined that one could achieve the same result in a single test by lighting all 20 cups. The elapsed time between lighting the cups and discharging the extinguisher, known as preburn, is critical in this configuration. Figure 2 shows the relationship between preburn and extinguisher performance.

The data clearly shows that preburn times greater than 50 seconds resulted in improved performance. Due to this effect, preburn time is limited to 30 seconds.

#### 2.5.1.2 Effect of Box Temperature on Extinguisher Performance.

To determine if the effect of preburn time was related to the elevated temperatures that occur with long preburns, the hidden fire test fixture was fitted with two 1000 watt heaters. This enabled testing at high interior temperatures without the long preburn times. The fixture was heated with the heaters to a temperature of 175°F. The extinguisher was discharged with a minimum preburn time of 5-10 seconds and the performance was recorded. At this elevated temperature, Halon 1211 consistently extinguished eight cup fires.

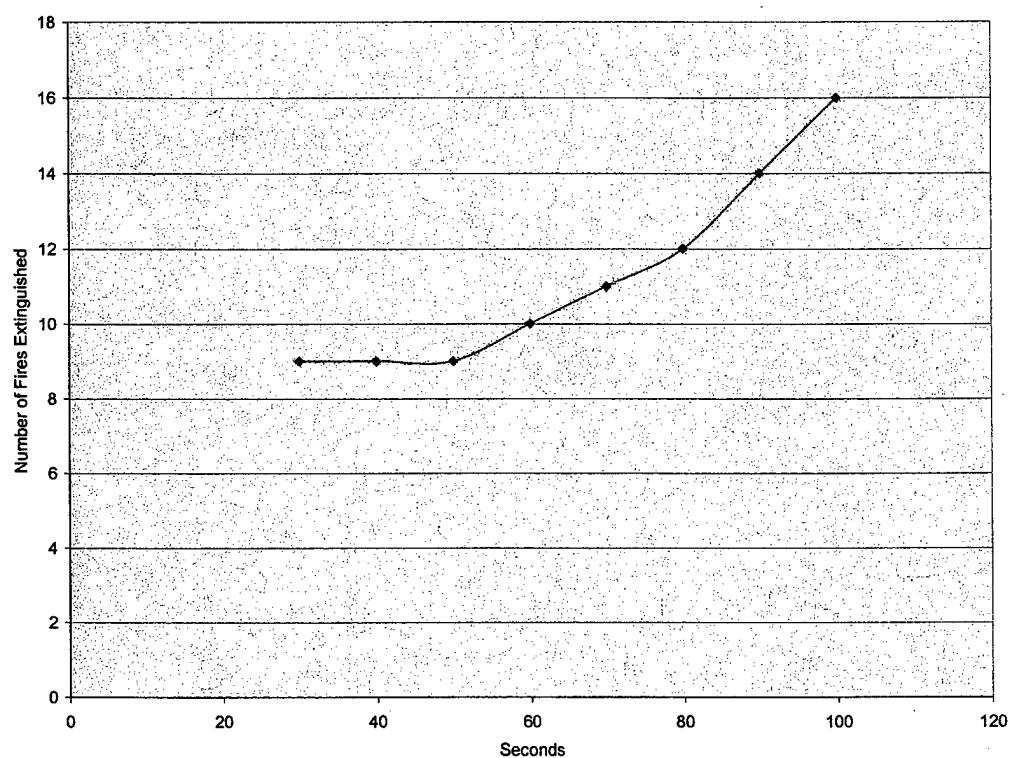


FIGURE 2. EFFECT OF PREBURN ON NUMBER OF FIRES EXTINGUISHED

To determine the effect of lower temperatures on extinguisher performance, the fixture was fitted with a room air conditioner. The interior temperature was lowered to 52°F. The extinguisher was again discharged with a minimum preburn time of 5-10 seconds and again consistently extinguished eight cups.

The tests were repeated at both high and low temperatures, this time with a preburn time of 30 seconds. In each test, Halon 1211 consistently extinguished nine cups. The effect of the temperature of the interior of the test fixture does not appear to have any effect on the performance of Halon 1211. This allows for testing at normal ambient conditions.

### 2.5.1.3 Effect of Nozzle Orientation on Extinguisher Performance.

The orientation of the discharge nozzle is critical to repeatable performance of the hidden fire test. Tests that were conducted with the discharge nozzle orientation varied both vertically and horizontally. All tests were performed with Halon 1211. The results are summarized in table 1.

TABLE 1. EFFECT OF NOZZLE ORIENTATION ON EXTINGUISHER PERFORMANCE

Nozzle Angle	Cup Fires Extinguished
0 Degrees	9
5 Degrees Left	13
10 Degrees Left	11
5 Degrees Right	9
10 Degrees Right	11
5 Degrees Up	13
10 Degrees Up	13
5 Degrees Down	10
10 Degrees Down	8

The data shows that the performance of an extinguisher charged with Halon 1211 is greatly affected by the angle of discharge. Care must be taken to insure that the nozzle is level and oriented parallel with the long sides of the test fixture.

The results of the preburn time tests, fixture temperature tests, and nozzle orientation tests are incorporated into the test procedure detailed in appendix A paragraph A.1, Hand-Held Fire Extinguisher Hidden Fire Test Method. When the preburn times are held to 30 seconds, the box temperature is at normal room temperature and the nozzle is oriented correctly, a 2.5-16 Halon 1211 extinguisher will consistently extinguish nine cup fires out of 20.

### 2.5.2 Effect of Ventilation Openings in Test Fixture.

Several tests were run to determine the effects of closing off the side ventilation ports. The ports are provided in the test fixture to simulate the air exchange rate normally encountered in the cheek area of an aircraft fuselage. Blocking the ventilation openings results in improved extinguisher performance. This is due to more agent being contained in the test fixture, possible oxygen starvation, and convective currents generated by the cup fires.

The closed ventilation configuration was determined to be a less realistic condition than having the ventilation ports open. The Minimum Performance Standard retains the open ventilation ports.

### 2.5.3 Replacement Agent Tests.

Several replacement agent and extinguisher manufacturers participated in the development of the Hidden Fire Test Method, including DuPont, American Pacific, and POWSUS. Each manufacturer provided charged extinguishers that were either in current manufacture or experimental preproduction models. Agents tested included DuPont FE-36, FE-36/FE-13,

Halotron 1, and two versions of Envirogel. The participation of these manufacturers enabled us to validate the test procedure.

a. DuPont FE-36

This is a gaseous agent that was not available in a production 5 BC extinguisher. The initial configuration resulted in seven cups extinguished. Different configurations were tested, including varying the amount of agent and charging pressure as well as changing the nozzle type and size. These changes resulted in achieving the nine cup minimum required to pass the Hidden Fire Test.

b. American Pacific Halotron

This is a gaseous agent that is currently available from several extinguisher manufacturers in a UL 5BC-rated unit. When tested, each of the commercially available units was able to extinguish seven to eight cups. The effects of varying the amount of agent, the charge pressure, and nozzle type and size resulted in achieving the nine-cup minimum required to pass the Hidden Fire Test.

c. POWSUS Envirogel

This is a powdered agent that is commercially available in a UL 5BC-rated extinguisher with either a phosphate powder or a bicarbonate powder. This agent, with either powder type, easily exceeded the minimum nine-cup requirement, extinguishing 12-18 cups. The test fixture required extensive cleaning after discharge of this agent.

The results of these tests should be considered informational only and not an endorsement for future certification.

## 2.6 DEVELOPMENT OF A PERFORMANCE AND TOXICITY TEST FOR HAND-HELD FIRE EXTINGUISHERS.

### 2.6.1 Seat Fire Toxicity Test.

The seat fire toxicity test was developed to provide a means for evaluating both the performance of replacement agents as well as determining the severity of any toxic byproducts produced during their use in extinguishing an in-flight fire. The basis for the test is the triple-seat fire test developed by Hill, et al. in the early 1980s. This test was developed in response to the hijacking/arsonist scenario that was prevalent in the late 1970s. The scenario consisted of an arsonist smuggling gasoline in a glass bottle onto an aircraft. The threat involved dumping the gasoline on a seat cushion and threatening to ignite it. In the tests performed by Hill, the performance of Halon 1211 greatly exceeded the then commonly used CO<sub>2</sub> and dry chemical extinguishers. The results of this work was incorporated into FAR Part 25.851 that requires Halon 1211 to be carried on all commercial passenger jets with more than 31 passengers.

The current performance/toxicity test retains the triple passenger seat used in Hill's earlier tests. However, the seats on modern aircraft are now fire-blocked. Fire blocking inhibits an external

fire from igniting the foam seat cushions, which would cause a much larger fire. The fire, provided by the ignition of a single quart of gasoline, spread across three seat bottoms, is a good test of the capabilities of a Halon 1211 UL 5BC extinguisher. As such, it provides a basis for comparison of the performance of replacement agents with the currently required Halon 1211.

#### 2.6.1.1 Seat Fire Toxicity Test Design.

##### 2.6.1.1.1 Test Facility.

The tests were performed in the forward cabin of the FAA William J. Hughes Technical Center's TC-10 aircraft fuselage. This is a fire-hardened fuselage designed to match the dimensions of a DC-10 aircraft. The fuselage is fitted with an adjustable ventilation system to provide a range of air exchanges within the cabin. For the purposes of this test, the air exchange rate was set one exchange every 5 minutes, simulating an in-flight condition.

##### 2.6.1.1.2 Instrumentation.

The cabin was fitted with three stations where the environmental gases were sampled for analysis (see figure 3). At each station, the concentration levels of oxygen, carbon dioxide, carbon monoxide, and neat agent were monitored continuously using infrared type analyzers. In addition, sample tubes were sequentially exposed to track the buildup of acid gases (primarily HF), measured by the Ion Chromatography method. Cabin air temperature was measured by three thermocouple trees. The fire severity was measured with a calorimeter.

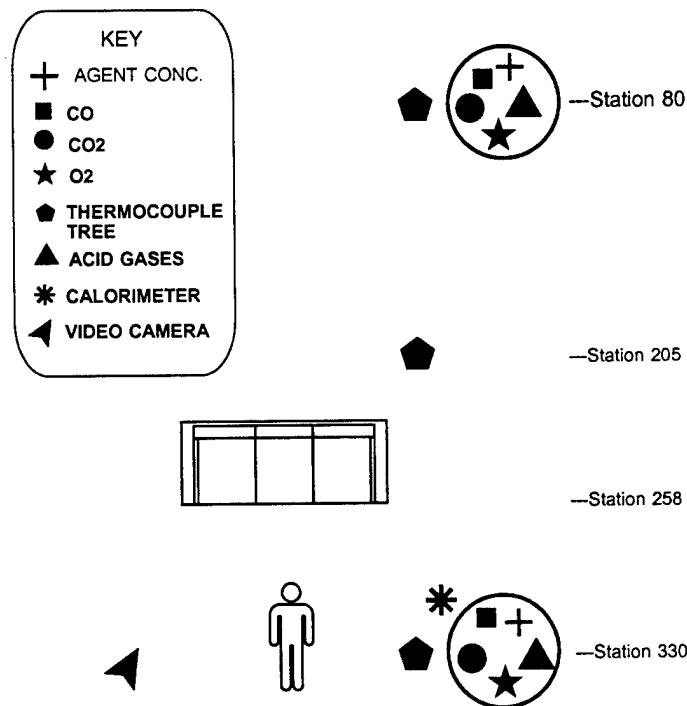


FIGURE 3. SEAT FIRE/TOXICOLOGY TEST INSTRUMENTATION  
TC-10 TEST ARTICLE

#### 2.6.1.1.3 Fire Load.

The fire load consisted of a metal frame with three seat bottoms and three seat backs. The seat cushions were aircraft-grade, fire-retardant foam rubber, encapsulated with Norfab™ fireblocking material, with a 90/10 wool decorative covering. The seat was fitted with a nichrome wire ignition source that was stretched across the middle seat bottom. A template was used to uniformly distribute 1 quart of gasoline, 1/3 quart on each seat bottom. The center cushion was ignited by a computer applying 110 volts AC to the nichrome wire at time 0:00. The fire quickly spread to the surrounding cushions and was allowed to propagate for 30 seconds. During this time, the decorative covering on the seat backs became involved in the fire, providing a 3-D fire scenario.

#### 2.6.1.1.4 Agent Application.

The initial design of this test specified the use of a remote firefighting device (robot). The robot proved to be too slow to effectively fight the fire and was replaced with a live firefighter in full protective turnout gear and breathing equipment. The same firefighter was used for all tests for continuity and consistency purposes. The firefighter was positioned 6 feet in front of the seat with the extinguisher's pin pulled and ready for discharge. A computer-controlled light was provided to signal the firefighter to begin extinguishing the fire at exactly 30 seconds from ignition. The firefighter used only the amount of agent required to extinguish the fire, leaving any residual agent in the extinguisher. Figures 4 and 5 show the firefighter extinguishing a practice fire.



FIGURE 4. FIREFIGHTER EXTINGUISHING PRACTICE FIRE IN TEST BAY—INITIAL AGENT APPLICATION

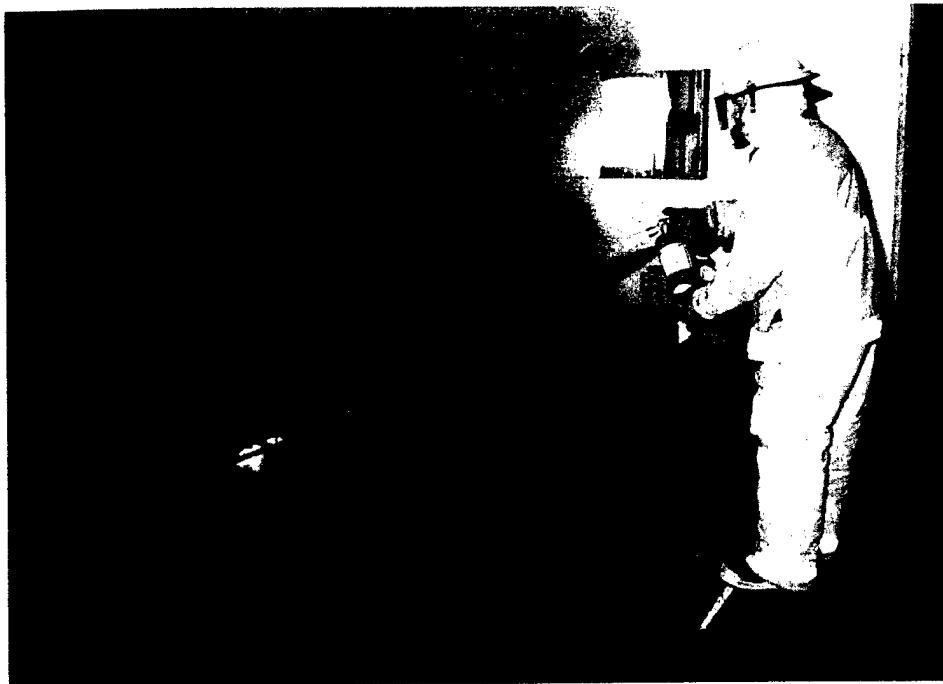


FIGURE 5. FIREFIGHTER EXTINGUISHING PRACTICE FIRE—  
SEAT EXTINGUISHED

2.6.1.1.5 Performance Measurement.

The extinguisher was weighed before and after the test to determine the quantity of agent required to extinguish the fire. The time required to extinguish the fire was also measured. A qualitative rating was also provided by the firefighter regarding the ease with which he was able to fight the fire.

2.6.1.1.6 Pass/Fail Criteria.

The agent had to be capable of extinguishing the seat fire. Analysis of the data revealed that the quantities of hydrogen fluoride (HF) produced by agent decomposition were of the most concern from a toxicity view point. A pass/fail criteria was developed for HF in conjunction with input from industry and the Environmental Protection Agency as follows:

- a. The concentration levels of HF could not exceed 200 ppm averaged over the highest 60-second interval, and
- b. The concentration levels of HF could not exceed 100 ppm averaged over the highest 4.5-minute interval.

2.6.1.2 Baseline Testing.

Baseline testing was performed in two modes. The first mode investigated the effects of allowing the fire to progress uncontrolled. This provided data on the environmental effects of the fire on the aircraft cabin in terms of cabin temperature and toxic gases produced. The second

mode provided a baseline performance and toxicity criteria using the currently specified Halon 1211 extinguisher to fight the fire.

## 2.6.2 TEST RESULTS.

A total of 27 tests were performed. These included three uncontrolled fires, three Halon 1211 tests, and three each for the replacement agents: DuPont FE-36, DuPont FE-36/FE-13, Great Lakes Chemical FM-200, North American Fire Guardian P IV, POWSUS Envirogel with bicarbonate powder, POWSUS Envirogel with phosphate powder, American Pacific Halotron 1. A complete summary of the test results including the peak gas values, cabin temperatures, and amount of agent used is shown in table 2.

### 2.6.2.1 Uncontrolled Fires.

To determine the danger posed by the fire conditions, three uncontrolled fires were performed. The triple seat/gasoline combination in an un-fire-blocked seat quickly leads to an out of control situation where the fire spreads to adjacent seats. This is not the case with a seat fitted with a fire-blocking layer. Typically, the fire consumes the gasoline and much of the decorative covering before self-extinguishing. The fires did not penetrate the fire-blocking layer, though some thermal charring of the foam cushion was noted. In each case, the decorative cover was severely damaged, but the seat itself was mainly intact. The fire generates a large amount of smoke, but the thermal hazard is minimal, peak cabin temperature reached a maximum of 114°F. No oxygen depletion is noted and very little HF is generated. The fire dies down to a minimum level in 1 1/2 minutes and completely self-extinguishes in less than 5 minutes.

### 2.6.2.2 Halon 1211 Baseline Tests.

Three tests were conducted using Halon 1211 to provide a performance and toxicity baseline. Halon 1211 extinguishes the seat fire with little difficulty and minimal extinguisher-handling technique is required. An average of 0.98 lb. of Halon 1211 was required to put the fire out. This left a reserve of 1.5 lb. in the standard 2.5-lb. UL 5BC extinguisher. Total charged weight of the extinguisher was 4.75 lb. Cabin temperatures never rose above 85°F in run 1, and the highest 1-minute average HF recorded was 21.04 ppm in run 2, and the highest 4.5-minute average was 13.87 ppm, also in run 2. The firefighter noted that he had little difficulty extinguishing the fire.

### 2.6.2.3 DuPont FE-36.

Three tests were conducted using DuPont FE-36. The extinguishers were not production models because there were none at the time of testing. Nominal charge weight was 5 lb. of agent. Total charged weight of the extinguisher was 9.5 lb. An average of 1.8 lb. of agent was required to extinguish the fire, with a reserve of 3.2 lb. Cabin temperatures peaked at 105°F in run 2. The highest 1-minute HF average was 102.85 ppm, and the highest 4.5-minute HF average was 67.42 ppm, both in run 2. The firefighter noted that the extinguisher was easy to use though heavy compared to the Halon 1211 extinguishers.

- Results: PASS

TABLE 2. DATA SUMMARY—SEAT FIRE TOXICOLOGY TESTS

Test	Peak Cabin Temperature Deg F	Heat Flux Btu/ft <sup>2</sup> -sec	HF 1-Minute Average (ppm)	HF 4.5-Minute Average (ppm)	Peak CO (%)	Minimum O <sub>2</sub> (%)	Agent Used Pounds	Peak Agent Conc. (%)	Discharge Time Seconds	Extinguish Seat?
Uncontrolled Burn #1	111	N/A	1.68	1.1	0.028	0.42	20.8	N/A	N/A	No
Uncontrolled Burn #2	114	0.61	0.87	0.53	0.021	0.35	20.9	N/A	N/A	No
Uncontrolled Burn #3	100	0.35	1.45	0.89	0.04	0.5	20.9	N/A	N/A	No
Halon 1211 #1	85	0.35	9.28	6.01	0.01	0.06	20.9	1.2	0.065	6
Halon 1211 #2	82	0.45	21.04	13.87	0.035	0.18	20.9	0.8	0.054	4.5
Halon 1211 #3	80	0.36	19.83	12.92	0.055	0.16	20.9	0.96	0.058	4.7
FE-36 #1	97	N/A	64.68	46.01	0.022	0.28	20.9	2	0.082	5
FE-36 #2	105	0.49	102.85	67.42	0.03	0.22	20.9	1.9	0.072	6
FE-36 #3	75	0.36	64.18	44.76	0.012	0.11	20.9	1.5	0.09	3.8
FE-36/FE-13 #1	90	0.48	110.7	83.09	1.01	0.2	20.9	3.7	0.3	8.1
FE-36/FE-13 #2	90	0.55	49.7	37.64	0.08	0.12	20.9	1.5	0.09	3.8
FE-36/FE-13 #3	89	0.55	97.58	63.88	0.011	0.12	20.9	1.3	0.08	3.2
POWSUS FE-36 Phosphate #1	85	0.36	14.31	10.26	none detected	0.14	20.9	1.6	N/A	4.4
POWSUS FE-36 Phosphate #2	86	0.35	20.2	11.85	none detected	0.1	20.9	0.8	N/A	2.1
POWSUS FE-36 Phosphate #3	88	0.38	11.56	10.62	none detected	N/A	20.9	1.8	N/A	4.9
POWSUS FE-36 Bicarb #1	77	0.37	20.48	13.94	none detected	0.1	20.9	0.94	0.06	2.4
POWSUS FE-36 Bicarb #2	76	0.34	42.36	28.22	none detected	0.11	20.9	1.85	0.07	4.8
POWSUS FE-36 Bicarb #3	65	0.3	21.04	13.84	0.01	0.11	20.9	0.88	0.06	2.3
Halotron 1 #1	95	0.49	23.87	16.59	0.015	0.19	20.9	2.1	0.05	4.9
Halotron 1 #2	82	0.45	25.76	20.13	0.05	0.15	20.9	2	0.07	4.7
Halotron 1 #3	89	0.55	21.82	13.54	0.02	0.14	20.9	2.3	0.11	5.5
FM 200 #1	101	0.41	63.81	45.18	0.015	0.12	20.9	2.55	N/A	4.4
FM 200 #2	85	0.4	104.25	74.44	0.022	0.11	20.9	1.91	0.12	4
FM 200 #3	92	0.38	65.77	46.37	0.21	0.2	20.9	4.14	0.17	8.3
NAFG PIV #1	96	0.49	25.33	17.86	0.18	0.19	20.9	4.44	0.43	7.8
NAFG PIV #2	77	0.48	38.17	21.12	0.19	0.2	20.9	5.01	0.4	8.2
NAFG PIV #3	71	0.42	41.59	32.22	0.25	0.12	20.9	4.17	0.46	7.4

#### 2.6.2.4 DuPont FE-36/FE-13.

Three tests were conducted using 4.5 lb. DuPont FE-36 mixed with 0.5 lb. of FE-13. The extinguishers were pressurized with nitrogen to 125 psi. Nominal charge weight was 5 lb. of agent. Total charged extinguisher weight was 11 lb. An average of 2.16 lb. of agent was required to extinguish the fire, leaving a reserve of 2.84 lb. Cabin temperatures peaked at 90°F in runs 1 and 2. The highest 1-minute HF average was 110.7 ppm, and the highest 4.5-minute HF average was 83.09 ppm in run 1. These numbers are significantly higher than those in runs 2 and 3 due to a reflash that required a second application of the agent. The firefighter noted that the extinguisher was effective with plenty of reserve capacity.

- Results: PASS

#### 2.6.2.5 POWSUS Envirogel With Phosphate Powder.

Three tests were conducted with the POWSUS Envirogel/phosphate powder. The extinguishers were nominally charged with 1 lb. of ammonium phosphate and 1.5 lb. of FE-36 for a total charge weight of 2.5 lb. of agent. Total charged extinguisher weight was 3.3 lb. An average of 1.4 lb. of agent was required to extinguish the fire, leaving a reserve of 1 lb. Cabin temperatures peaked at 88°F in run 3. The highest 1-minute HF average was 20.2 ppm, and the highest 4.5-minute HF average was 11.85 ppm, both in run 2. The firefighter noted that the extinguisher was as light as a Halon 1211 extinguisher and seemed to be as effective. The powder did not linger in the air very long and did not obscure the firefighters vision.

- Results: PASS

#### 2.6.2.6 POWSUS Envirogel With Bicarbonate Powder.

Three tests were conducted with the POWSUS Envirogel/bicarbonate powder. The extinguishers were nominally charged with 1 lb. of bicarbonate powder and 1.5 lb. of FE-36 for a total charge weight of 2.5 lb. Total charged extinguisher weight was 3.3 lb. An average of 1.22 lb. of agent was required to extinguish the fire, leaving 1.28 lb. of agent in reserve. Cabin temperatures peaked at 77°F in run 1. The highest 1-minute HF average was 42.36 ppm, and the highest 4.5-minute HF average was 28.22 ppm, both in run 2. The firefighter noted that the agent was very effective though the powder lingered in the air longer than the phosphate version. The light weight of the extinguisher made it easy to handle.

- Results: PASS

#### 2.6.2.7 American Pacific Halotron 1.

Three tests were conducted with American Pacific Halotron 1. The extinguishers were nominally charged with 5 lb. of agent. Total charge weight of the extinguisher was 8.3 lb. An average of 2.13 lb. of agent was required to extinguish the fire, leaving 2.87 lb. of agent in reserve. Cabin temperatures peaked 95°F in run 1. The highest 1-minute HF average recorded was 25.76 ppm, and the highest 4.5-minute HF average was 20.13 ppm, both in run 2. The

firefighter noted that the extinguisher was effective, requiring a sweeping technique to extinguish the fire.

- Results: PASS

#### 2.6.2.8 Great Lakes Chemical FM-200.

Three tests were conducted with Great Lakes Chemical FM-200. The extinguishers were nominally charged with 5.75 lb. of agent. Total charged weight of the extinguisher was 8.9 lb. An average of 2.86 lb. of agent was required to extinguish the fire, leaving 2.89 lb. in reserve. Cabin temperatures peaked at 101°F in run 1. The highest 1-minute HF average was 104.25 ppm, and the highest 4.5-minute HF average was 74.44 ppm, both in run 2. The firefighter noted that the agent was effective with plenty of reserve.

- Results: PASS

#### 2.6.2.9 North American Fire Guardian (NAFG) P IV.

Three tests were conducted with North American Fire Guardian P IV. The extinguishers used in this series were UL 10BC models due to unavailability of UL 5BC model. The extinguishers were nominally charged with 8.6 lb. of agent. Total charged weight of the extinguisher was 15.73 lb. An average of 4.54 lb. of agent was required to extinguish the fire. No determination of reserve capacity is possible due to the larger size extinguisher used. Cabin temperatures peaked at 96°F. The highest 1-minute HF average was 41.59 ppm, and the highest 4.5-minute HF average was 32.22 ppm, both in run 3. The firefighter noted that he used more agent to extinguish the fire than with the other test extinguishers.

- Results: PASS

### 2.6.3 Results Summary.

Each of the candidate agents easily passed the HF toxicity requirement. The firefighter was able to extinguish the fire with each agent with a comfortable margin of reserve agent to handle flareups. All of the replacement candidate extinguishers weighed approximately twice as much as the Halon 1211 extinguishers that they are replacing with the exception of the POWSUS extinguishers, which are somewhat smaller and lighter. All of the replacement candidate agents required more firefighter technique than Halon 1211, each needing to be applied in a sweeping motion at the base of the fire, whereas Halon 1211 can be applied by just pointing and holding at the base of the fire.

Note that passing the toxicity test is only one half of the certification process. Each agent/extinguisher combination will also have to pass the hidden fire test detailed in section 2.5.

## 3. CONCLUSIONS.

- The hidden fire test has been shown to be an effective tool in determining the firefighting flooding capabilities of a hand-held fire extinguisher.

- The hidden fire test is highly repeatable when operated under the procedures detailed in the minimum performance standard.
- The hidden fire test is not ambient temperature sensitive under the range of 60° to 100°F.
- The hidden fire test is sensitive to nozzle orientation.
- The hidden fire test is sensitive to preburn times longer than 50 seconds.
- The following replacement agents have been determined to be safe when used to extinguish a seat fire in an aircraft cabin: DuPont FE-36 and FE-36/FE-13, Halotron 1, FM200, Envirogel bicarbonate, Envirogel phosphate, and NAFG P IV.
- Fire-blocked seats have mitigated the threat imposed by the arsonist scenario.
- All of the gaseous replacement agents require approximately twice as much agent by weight as Halon 1211.
- All of the replacement agents require more firefighter technique than Halon 1211.

#### 4. REFERENCES.

1. Hill, R. G. and Speitel Louise, "In-Flight Aircraft Seat Fire Extinguishing Tests (Cabin Hazard Measurements)," FAA Technical Center, DOT/FAA/CT-82/111, December 1982.
2. Chattaway, A., "The Development of a Hidden Fire Test for Aircraft Hand Extinguisher Applications," Kiddle International, R95/11, November 1995.

## APPENDIX A—MINIMUM PERFORMANCE STANDARD FOR HAND-HELD FIRE EXTINGUISHERS

### A.1 HAND-HELD FIRE EXTINGUISHER HIDDEN FIRE TEST.

#### A.1.1 PURPOSE.

The purpose of this test is to evaluate the effectiveness of candidate replacement hand-held streaming agents against an aircraft hidden fire requiring agent flooding characteristics. Halon 1211, a streaming agent, has been shown to be an effective flooding agent, both in this test and in aircraft during the extinguishment of hidden fires. This test will ensure that there is no loss of safety when newer, more environmentally friendly agents replace Halon 1211 in service.

#### A.1.2 BACKGROUND.

Halon 1211 was initially selected for use in aircraft cabins in response to the hijacking/arsonist scenario. This scenario, consisting of gasoline splashed on a seat cushion and ignited, is still a concern and is the basis for the second performance test described in appendix A, paragraph A.2. It was later determined that Halon 1211, while primarily a streaming agent, provided the capacity to act as a flooding agent. This was demonstrated on several in-flight hidden fire incidents in large transport aircraft, possibly preventing the loss of the aircraft. KIDDE International, UK, developed the test described in this section [A-1]. The operating procedure has been refined and standardized at the Federal Aviation Administration (FAA) William J. Hughes Technical Center, USA.

#### A.1.3 TEST DESCRIPTION.

A candidate fire extinguisher is discharged into the left side of a rectangular box. Inside the box are 20 small cup fires arranged in five arrays of four. The arrays are separated by solid and perforated baffles. The baffles require the agent to extinguish the fire by indirect means. The extinguisher is discharged fully and the total fires extinguished are counted. Baseline testing with Halon 1211 extinguished nine fires.

#### A.1.4 TEST APPARATUS.

The test is conducted in a rectangular box 2 meters high, 2 meters long, and 1/2 meter wide. One long side of the box is fitted with clear Plexiglas to allow an unobstructed view of the interior. The interior of the box is fitted with 20 metal cups, 35 mm in diameter, arranged in three vertical arrays of four cups and one vertical array of eight cups (figure A-1). The baffles are perforated to allow a 33-percent hole area to separate the arrays (figure A-2). The lower end of each baffle is fitted with solid stop plates, in line with the extinguisher injection port. The first three arrays and the top four cups of the fourth array are installed in the upper half of the test fixture. The lower four cups of the fourth array are installed in the lower half of the fixture. Two ventilation ports are cut into the left side of the box, at the top and bottom of the fixture. A 2-inch hole is cut into the same side, through which the extinguisher agent is introduced (figure A-3). Figures A-4 and A-5 show a detail of the cups and cup-mounting brackets.



FIGURE A-1. HIDDEN FIRE TEST APPARATUS WITH FRONT DOORS OPEN



FIGURE A-2. DETAIL OF CUP LOCATIONS AND BAFFLE PLATES

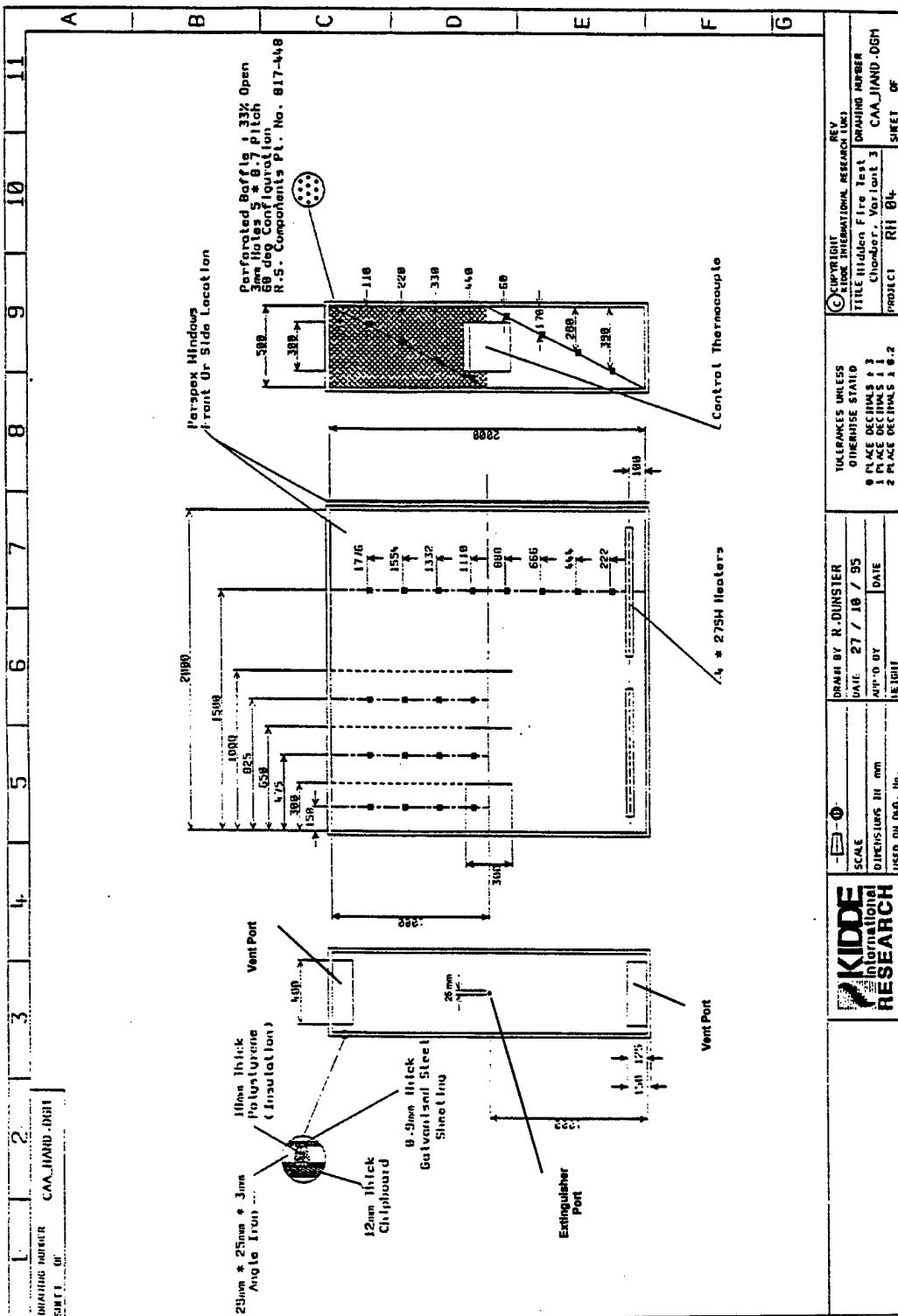




FIGURE A-4. CLOSE-UP OF FIRE CUP

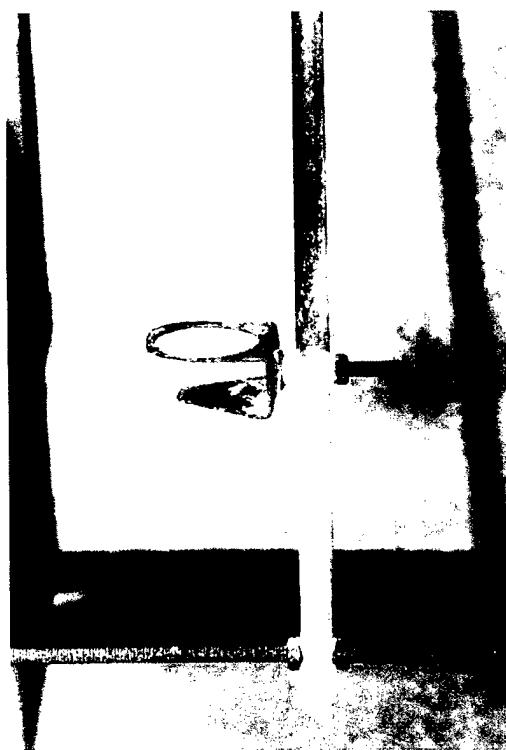


FIGURE A-5. CUP-MOUNTING BRACKET

#### A.1.4.1 Fire Loading.

The 20 cups in the four arrays are loaded with 10 ml of water and 5 ml of n-Heptane, floated on top of the water.

### Instrumentation.

The interior temperature of the box is measured in a central location near the top of the fixture. The temperature is to be recorded prior to each test. The test is recorded on videotape.

### Extinguisher Rating.

The candidate extinguisher must be approved by a recognized fire-testing laboratory and have a minimum rating of UL 5BC, or an equivalent rating to 2.5 pounds of Halon 1211.

### A.1.5 TEST PROCEDURE.

This test is to be performed 5 times for each extinguisher/agent combination to be certified. The results from the five tests are to be averaged. Subsequent changes in hardware that affect the spray pattern, or discharge time, or quantity and formulation of agent, require that the extinguisher be recertified.

- a. Operating Temperature: The test fixture and the extinguishers are to be equilibrated at a temperature of 70°-90°F. If successive tests are to be run, the test fixture must be allowed to cool to the prescribed temperature.
- b. Agent Weight: The extinguisher is to be weighed before and after discharging to determine the weight of the agent discharged.
- c. Extinguisher Mounting: The loaded extinguisher is mounted on the side of the fixture such that the nozzle is directed through the 2-inch hole in the left side of the fixture. Care must be taken with the nozzle orientation to insure that the discharge stream is level and centered left to right through the discharge port. Figure A-6 and A-7 show the mounting of extinguishers with fixed and hose equipped nozzles.
- d. Fire Loading: The cups are loaded with 10 ml of water and 5 ml of n-Heptane and ignited. The access doors are closed at this time. A preburn of 30 seconds is timed from the closing of the access doors.
- e. Extinguisher Discharge: The extinguisher is discharged fully at the end of the 30 second preburn. A stopwatch is used to measure the discharge time.
- f. Test Results: The number of fires extinguished up to 60 seconds after discharge is noted. Figure A-8 contains a sample hidden fire test record form.

At the conclusion of the test, the access doors are to be opened to vent the fixture and any remaining fires are extinguished. The temperature in the box is allowed to return to 70°-90°F. The remaining contents of the cups are emptied and the cups are cleaned to remove any residue to insure that subsequent tests are not compromised.



FIGURE A-6. FIXED NOZZLE EXTINGUISHER MOUNTED TO SIDE OF  
HIDDEN FIRE TEST APPARATUS



FIGURE A-7. HOSE NOZZLE EXTINGUISHER MOUNTED TO SIDE OF  
HIDDEN FIRE TEST APPARATUS

FIGURE A-8. SAMPLE HIDDEN FIRE TEST RECORD FORM

## A.1.6 TEST REPORT.

A report is generated at the end of each series containing the following information:

Agent, extinguisher manufacturer, extinguisher rating, extinguisher model and serial numbers, weight of agent, fixture temperature at the start of the test, number of fires extinguished for each test, average number of fires extinguished for the series of five tests.

### A.1.7 MINIMUM PERFORMANCE.

The candidate replacement agent must extinguish a minimum of nine fires when averaged over the five tests.

## A 1.8 EXTINGUISHER LABELING

Each extinguisher that meets the requirements of the Minimum Performance Standard must be labeled as follows: FAA Approved. Meets the Minimum Performance Standard as a replacement for Halon 1211 as per report DOT/FAA/AR-01/37.

## A.2. SEAT FIRE/TOXICOLOGY TEST (HIJACKING/ARSONIST SCENARIO).

### A.2.1 PURPOSE.

The objectives of this test are to evaluate the performance of a candidate replacement hand-held agent under in-flight conditions to insure that there is no loss of safety in terms of agent firefighting performance and occupant exposure to toxic decomposition by-products. Unlike the Hidden Fire Test, this test will certify an agent, not an agent/extinguisher combination.

### A.2.2 BACKGROUND.

The basic parameters for this test were developed at the Federal Aviation Administration (FAA) William J. Hughes Technical Center as described in reference A-2. The test was designed to (1) determine the amount of toxic decomposition by-products from the extinguishment of large seat fires with hidden 1211 in an aircraft cabin while in flight, (2) compare the relative hazard levels from the use of common aircraft hand-held extinguishers (Halon 1211, monoammonium phosphate, carbon dioxide, water), and (3) compare the hazards from the extinguishment of a large aircraft seat fire to the hazards of an uncontrolled fire.

The current test has essentially the same goals applied to replacement agents for Halon 1211. The test has been modified to include the use of fire-blocked seats required by FAA regulations adopted in 1984 and an extended (30 seconds) preburn. The use of the remote controlled fire-extinguishing unit in the 1982 study was discontinued due to the slow reaction time and replaced by an experienced firefighter in full turnout gear and self-contained breathing unit.

### A.2.3 TEST DESCRIPTION.

A triple fire-blocked seat is installed in the cabin of the TC-10 test article. Airflow conditions in the test article are set to simulate in-flight conditions at one air exchange every 5 minutes. The seat is primed with 1 quart of automotive gasoline on top of the base cushions. The seat is ignited and allowed to burn for 30 seconds. Gas and temperature data collection is initiated at the moment the seat is ignited. A firefighter is positioned 6 feet forward of the seat with the extinguisher ready. The firefighter extinguishes the fire 30 seconds after ignition as efficiently as possible. Data collection continues for 3 minutes after the ignition point.

### A.2.4 TEST ARTICLE.

The TC-10 full-scale wide-body test article is used for this test program. The cabin is equipped to simulate in-flight air ventilation conditions at the rate of one air exchange every 5 minutes. The cabin is fitted with a single triple-seat stand. The six cushions that make up the three seats are made up of fire-retardant foam, Norfab™ fire-blocking layer, and covered with a 90/10 wool decorative material.

### A.2.5 INSTRUMENTATION.

The type and location of all instrumentation is shown in figure A-9. Cabin temperature profiles were measured using 24-gauge chromel-alumel type K thermocouples. A calorimeter, calibrated in the 0-5 Btu/ft<sup>2</sup>-sec range was installed at the discharge point to measure the intensity of the fire. Carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), oxygen (O<sub>2</sub>), and the neat agent concentrations (where possible) were measured using Beckman continuous infrared analyzers. The acid and organic gases were collected and analyzed as follows:

- a. Acid Gas Collection. Absorption tubes were used to collect acid gas samples during the tests. Each tube is made up of glass-lined stainless steel, 16 1/2 centimeters long with a 4-millimeter inside diameter, attached to a 10.16 cm-long glass tube with a 2-mm internal diameter. It is packed to a depth of 14 centimeters with 3-millimeter-diameter glass beads, which are held in place by a slice of Teflon pressed into the tube at each end. The beads are rinse coated with 0.025 Molar (M) Sodium Hydroxide (NaOH) just prior to use, excess solution being blown from the tube by syringe. The absorption tubes are housed in an ice-water solution in an aluminum box, which is insulated with Kaowool<sup>TM</sup> ceramic board. The horizontally mounted tubes are held in place by drilled through watertight bulkhead fittings. The outside glass ends extend one inch beyond the insulation. The interior ends are attached to separate vacuum lines, which pass through the bottom of the box and lead to the solenoid valve assembly. A flow rate of 0.78 liters per minute is drawn during the test. The solenoid valves are programmed to open sequentially as shown in table A-1.

The anion samples are recovered for analysis by rinsing the absorption tubes with a 0.025 NaOH solution dispensed by syringe. The filtered washings are collected in autosampler plastic cuvettes for subsequent analysis.

- b. Acid Gas Analysis. Hydrogen fluoride, hydrogen chloride, and hydrogen bromide were identified and quantified by ion chromatography (IC). The method and instrumentation used for the anion analysis are described in table A-2.

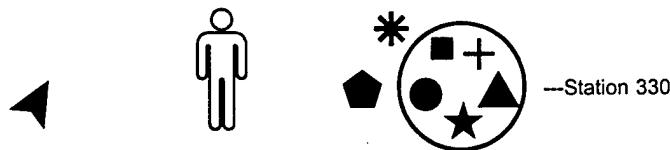
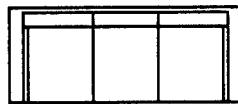
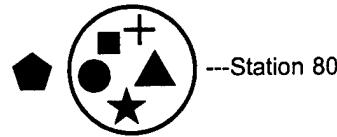
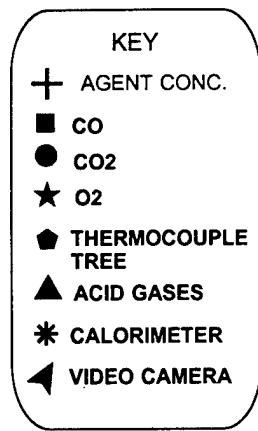


FIGURE A-9. SEAT FIRE/TOXICOLOGY TEST INSTRUMENTATION  
TC-10 TEST ARTICLE

TABLE A-1. SOLENOID VALVE SEQUENCE

Solenoid Valve	Time Open*	Time Close	Duration
1	0:00	0:30	0:30
2	0:30	1:00	0:30
3	1:00	1:30	0:30
4	1:30	2:00	0:30
5	2:00	2:30	0:30
6	2:30	5:00	2:30
7	5:00	10:00	5:00

\*All times are in minutes and seconds.

TABLE A-2. ACID GAS METHOD OF COLLECTION AND ANALYSIS

Gases	Sampling System	Instrument	Method	Comments																					
HF, HCl, and HBr	Time sequenced batch sampling:  10 time sequenced sampling tubes and two control tubes: all are 4 mm id, filled with 3-mm-glass beads coated with a 0.25M NaOH solution, with a glass extension tube of 2 mm-id. Flowmeter, filter, and vacuum pump downstream. Tubes housed in an ice water bath at point of sampling.	Dionex DX 500 Chromatography System with GP40 Gradient Pump w/Degas, LC30 Chromatography Oven, ED40 Electrochemical Detector with <i>conductivity cell</i> , DS3 Detection Stabilizer (temperature control chamber for conductivity cell), AS3500 programmable Autosampler with sample prep, Peaknet Chromatography Data Acquisition System on IBM compatible PC.	<p>Ion Chromatography Gradient Elution.</p> <p>Ionpac AS10 Analytical Column (4 x 250 mm), Ionpac AG10 Guard Column</p> <p>Eluent A: 200mMNaOH</p> <p>Eluent C: Water</p> <p>Total flow: 1.0ml/min</p> <table> <thead> <tr> <th>Time (min)</th> <th>%A</th> <th>%C</th> </tr> </thead> <tbody> <tr> <td>0.00</td> <td>10</td> <td>90</td> </tr> <tr> <td>5.00</td> <td>10</td> <td>90</td> </tr> <tr> <td>20.00</td> <td>75</td> <td>25</td> </tr> <tr> <td>35.00</td> <td>75</td> <td>25</td> </tr> <tr> <td>35.10</td> <td>10</td> <td>90</td> </tr> <tr> <td>45.00</td> <td>10</td> <td>90</td> </tr> </tbody> </table>	Time (min)	%A	%C	0.00	10	90	5.00	10	90	20.00	75	25	35.00	75	25	35.10	10	90	45.00	10	90	<p>IC method provides a good separation of light organics from Fluoride peak.</p> <p>IC Method developed by Dionex for FAA combustion gas samples:</p>
Time (min)	%A	%C																							
0.00	10	90																							
5.00	10	90																							
20.00	75	25																							
35.00	75	25																							
35.10	10	90																							
45.00	10	90																							

A.2.6 EXTINGUISHER RATING.

The candidate extinguisher must be approved by a recognized fire-testing laboratory and have a minimum rating of UL 5BC, or an equivalent rating to 2.5 pounds of Halon 1211.

A.2.7 SEAT CUSHIONS.

The seat cushions are to be identical for all tests. The cushion is made up of fire-retardant foam, Norfelt seat-blocking layer, and 90/10 wool decorative covering. The seat base foam dimensions are 18" by 20" by 4". The seat back dimensions are 17" by 25" by 2".

A.2.8 PRACTICE FIRES.

The firefighter will extinguish a minimum of two seat fires to familiarize himself with the characteristics of the candidate extinguisher. These fires will use the same seat cushion/fire blocking/coverings as will be used in the data tests. Instruction for any special techniques required for the efficient extinguishment of the fire will be supplied by the manufacturer.

A.2.9 NUMBER OF DATA TESTS.

The Seat Fire/Toxicology Test shall be performed three times for a candidate agent.

A.2.10 TEST PROCEDURE.

- The extinguisher is equilibrated at normal room temperature and weighed before and after discharge to determine the amount of agent used. The extinguisher is fitted with a mechanism to record the discharge time.
- The seat cushions are equilibrated at room temperature prior to installation on the seat frames.

- c. The center seat base is fitted with a length of nichrome wire stretched across the top of the cushion. When energized with 110 volt AC current, this will supply the ignition source.
- d. Cabin ventilation is turned on.
- e. The firefighter, with the extinguisher, is positioned in the cabin, well back from the seat.
- f. The seat is primed with 1 quart of automotive gasoline poured across the forward one third of the three seat bases.
- g. The cabin is sealed.
- h. The data systems are started and verified.
- i. The seat is ignited, gas collection begins.
- j. The firefighter advances to the burning seat and stands at a mark 6 feet from the forward edge of the lower cushion.
- k. At 30 seconds after ignition, the firefighter begins to extinguish the burning seat using only as much agent as is necessary to extinguish the fire.
- l. Data and gas collection continue until 10 minutes from the ignition point.
- m. The test is terminated at this time and the cabin is ventilated and the gas collection cylinders are retrieved for analysis.

#### A.2.11 TEST REPORT.

A report is generated at the end of the series with the following information:

Agent, extinguisher manufacturer, extinguisher rating, extinguisher model and serial numbers, weight of agent used, extinguisher discharge time, graphs for cabin temperature, carbon dioxide, carbon monoxide, oxygen, agent concentration, toxic gases.

#### A.2.12 MINIMUM PERFORMANCE.

The candidate replacement agent must be capable of extinguishing the seat fire. The levels of hazardous gases generated by the interaction of the agent and the fire as well as the neat agent must not exceed dangerous levels.

Analysis of the data indicate that Hydrogen Fluoride (HF) is the primary hazardous decomposition product. The proposed limits for HF are as follows:

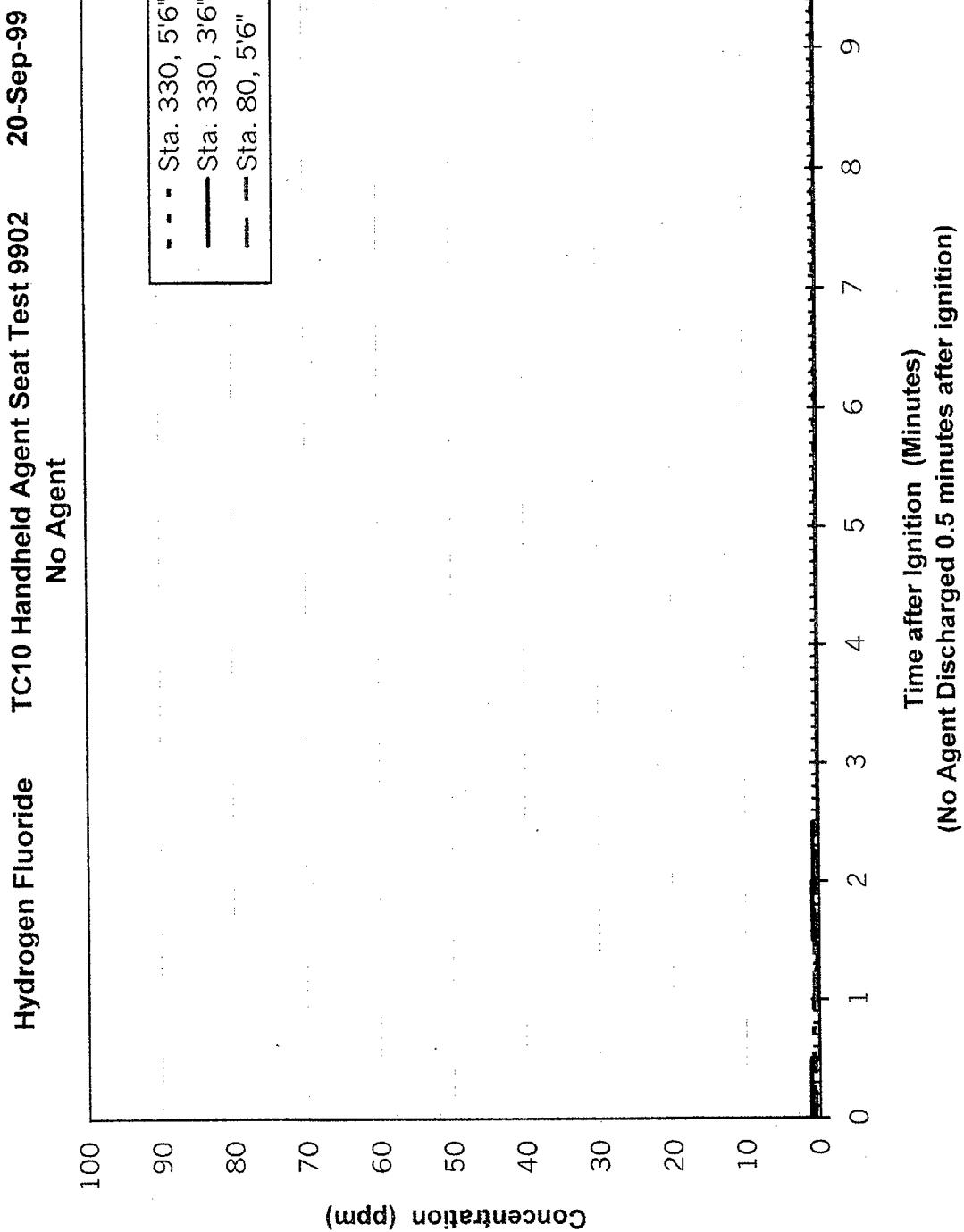
- a. The average concentration of HF shall not exceed 200 ppm for any 1-minute period.
- b. The average concentration of HF shall not exceed 100 ppm for any 4 1/2-minute period.

### A.3 REFERENCES.

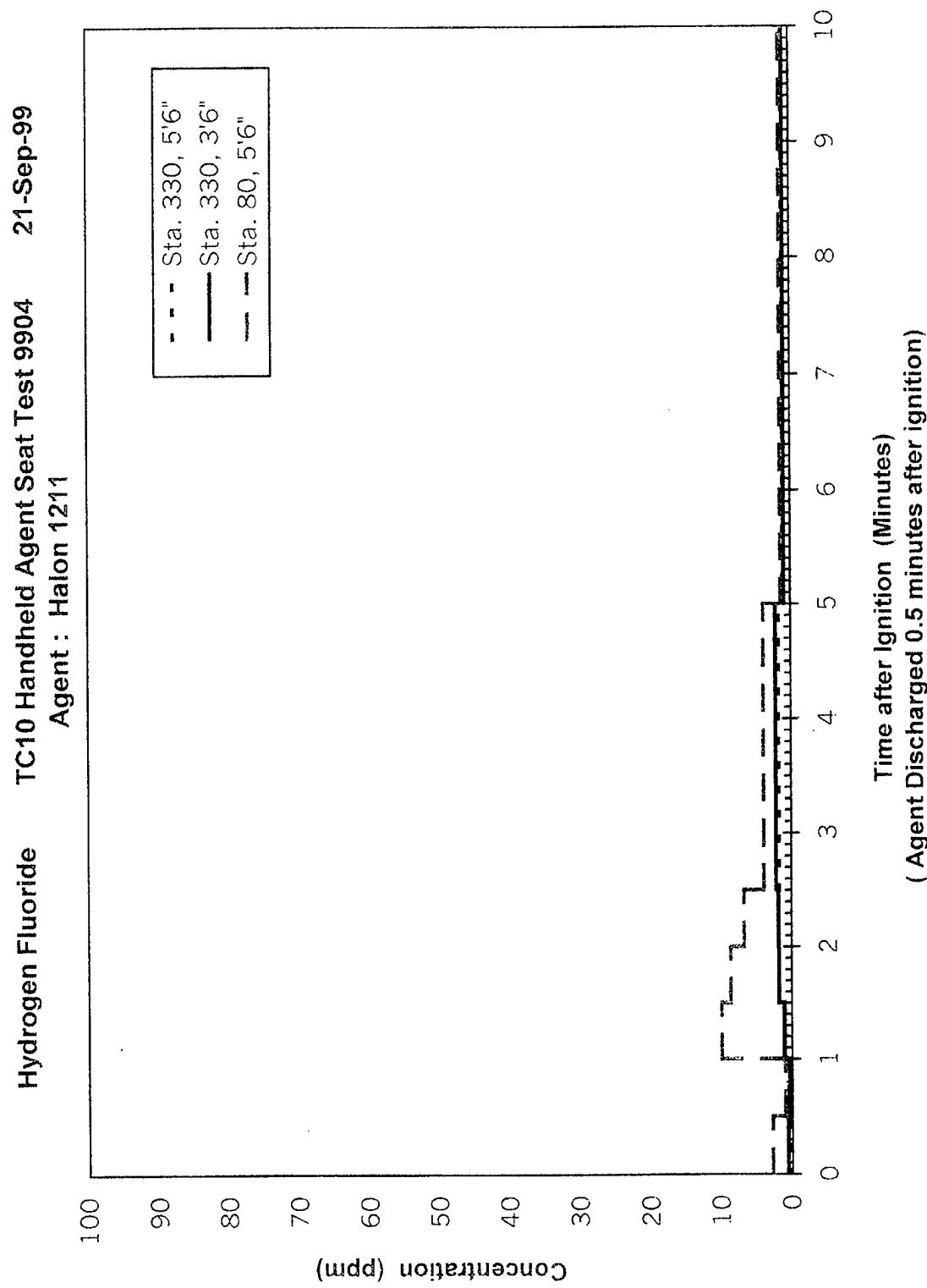
- A-1 Chattaway, A., "The Development of a Hidden Fire Test for Aircraft Hand Extinguisher Applications," Report No. R95/11, November 1995.
- A-2. Hill, R.G. and Speitel, L.C., "In-Flight Aircraft Seat Fire Extinguishing Tests (Cabin Hazard Measurements), FAA Technical Center, DOT/FAA/CT-82/111, December 1982.

## APPENDIX B—SAMPLE HYDROGEN FLUORIDE GAS CONCETRATION DATA

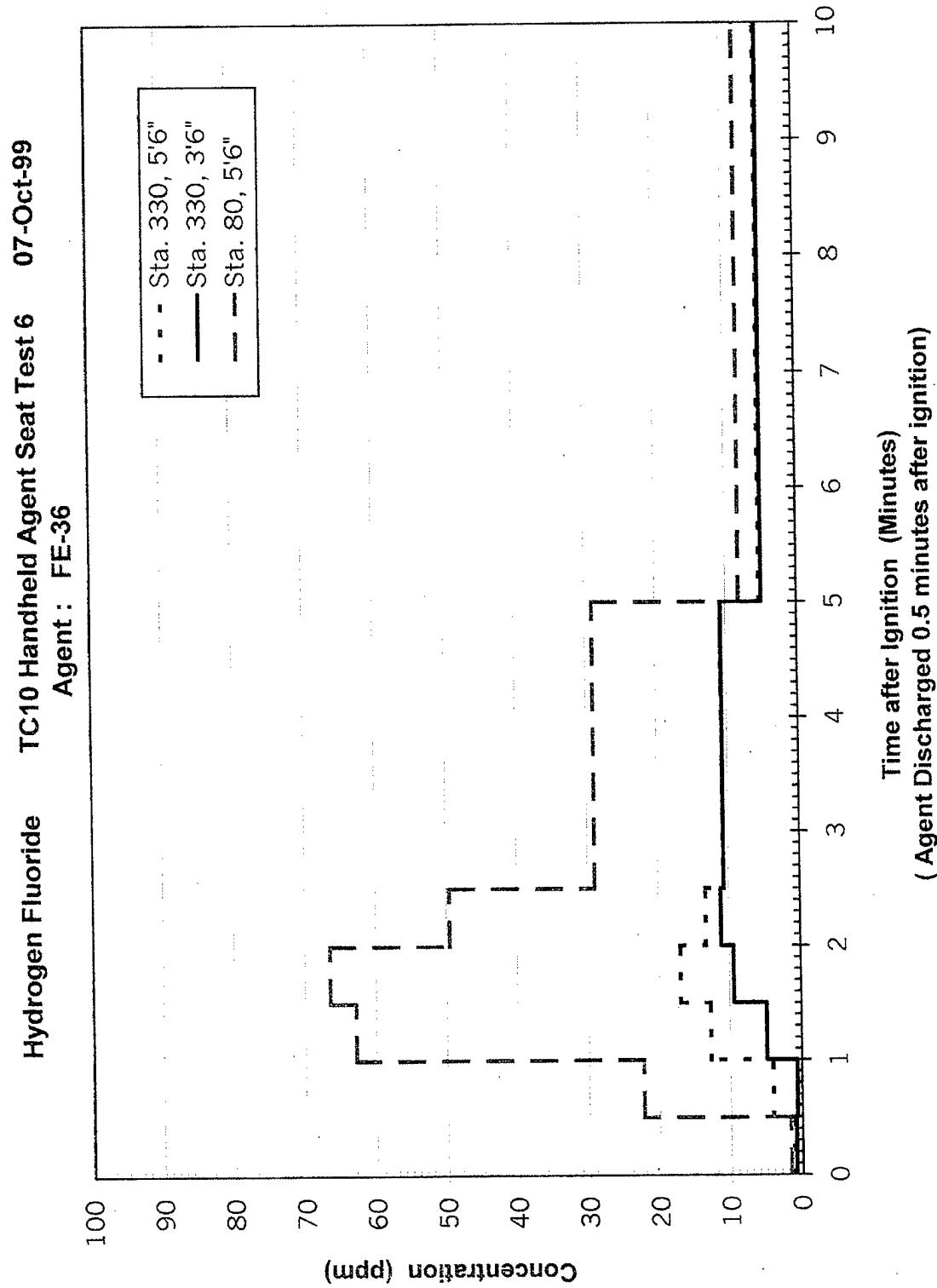
### B.1 UNCONTROLLED FIRE SAMPLE DATA.



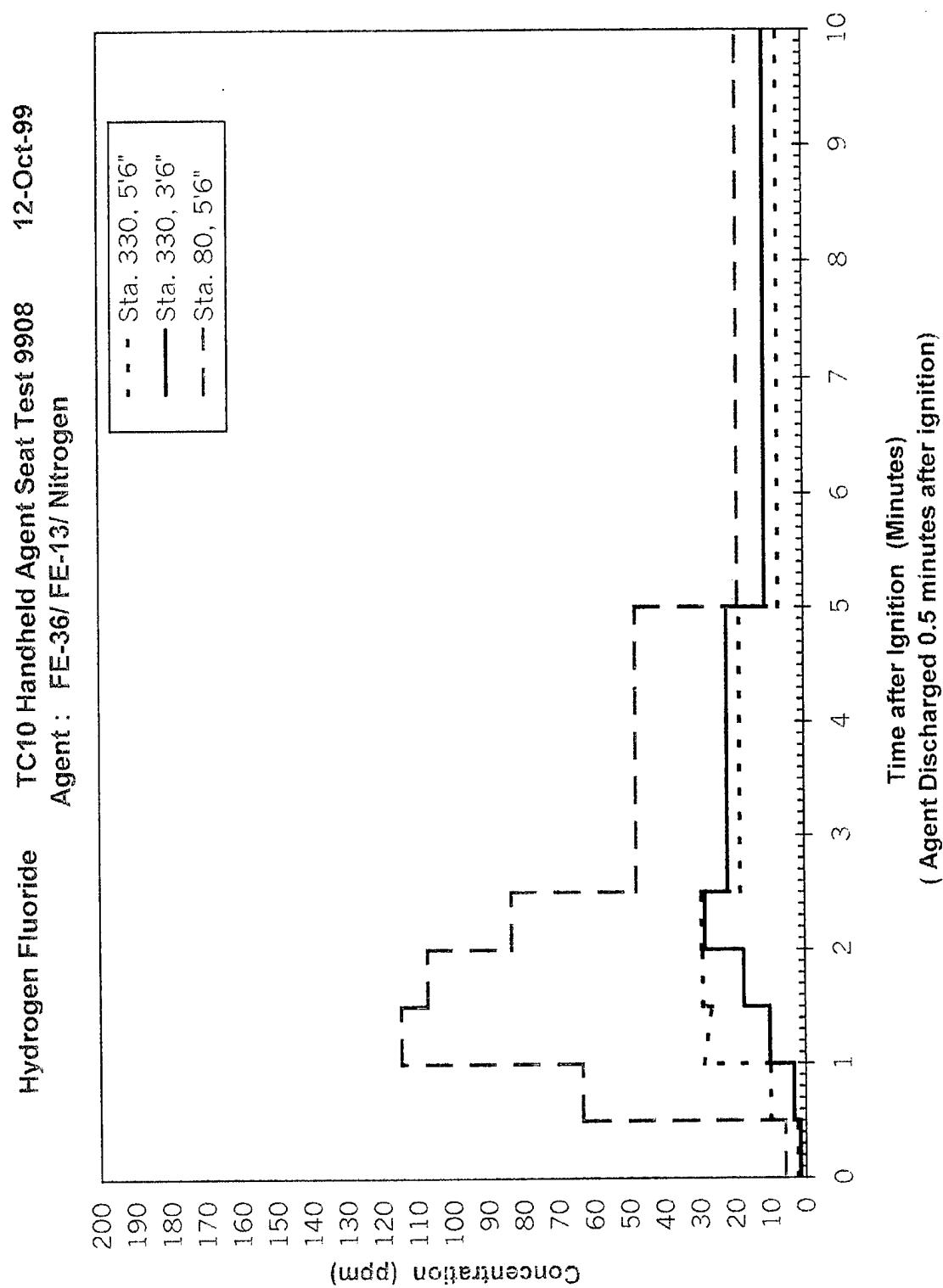
B.2 HALON 1211 SAMPLE DATA.



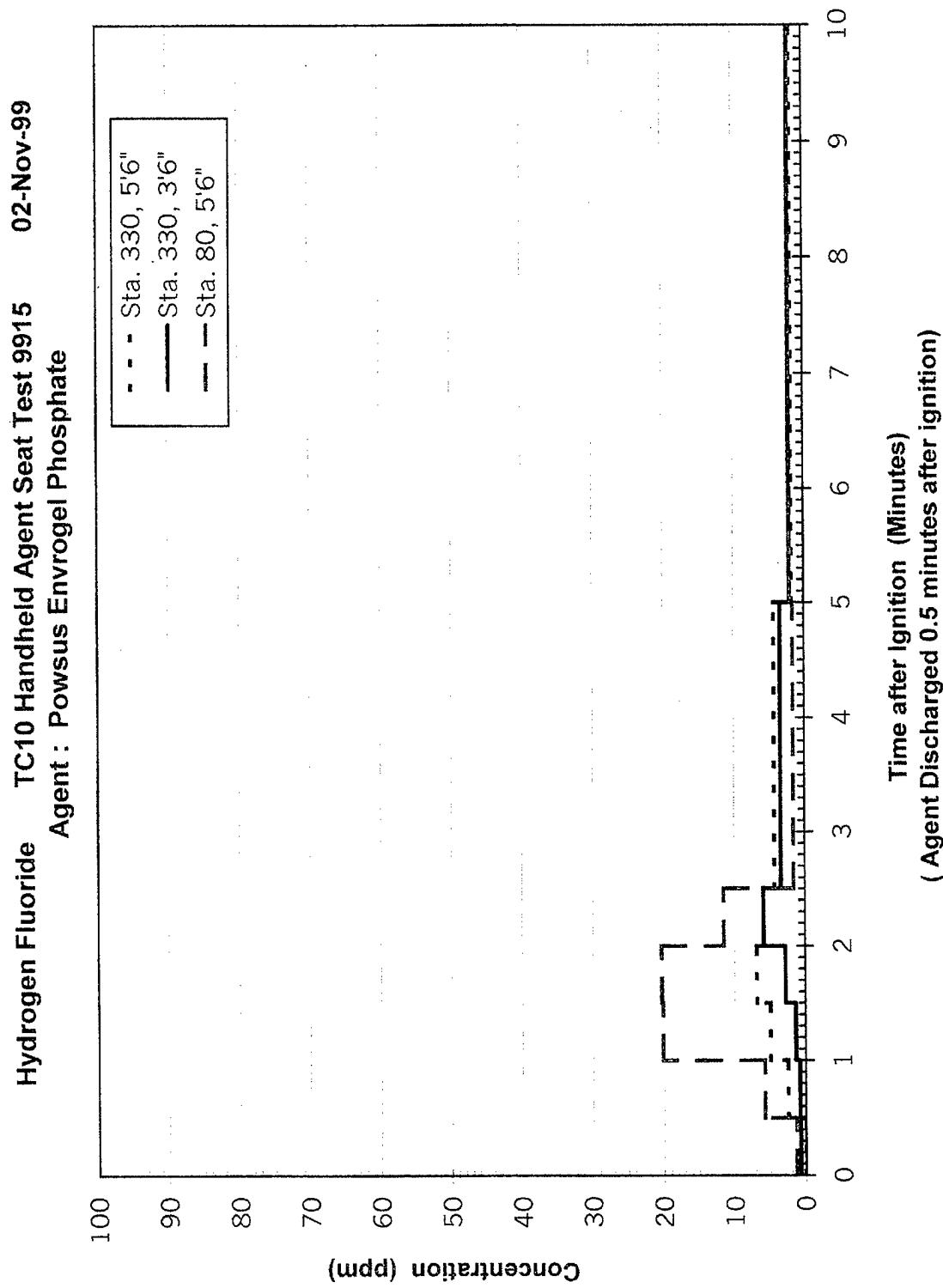
B.3 DUPONT FE-36 SAMPLE DATA.



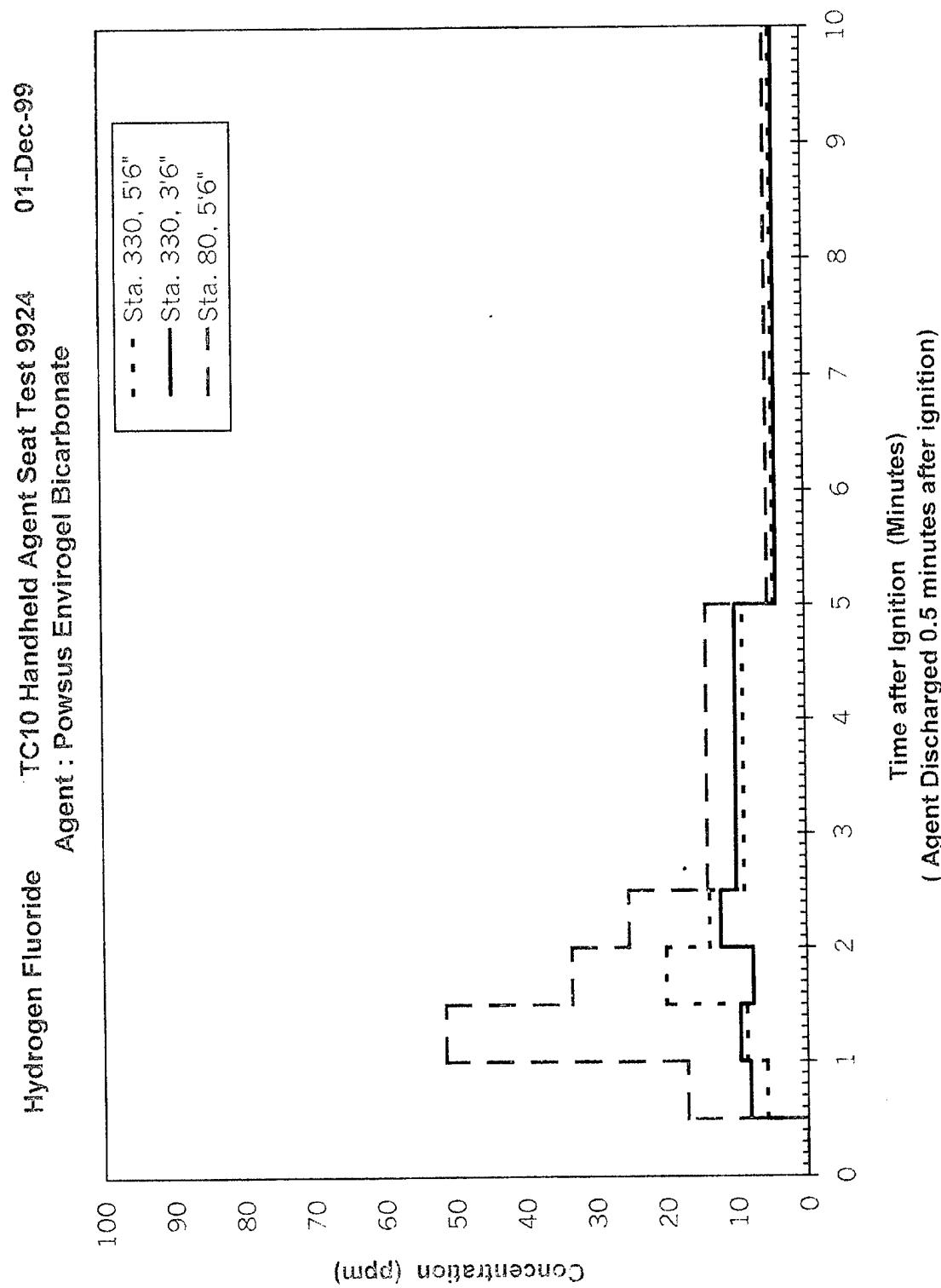
B.4 DUPONT FE-36/FE-13 SAMPLE DATA.



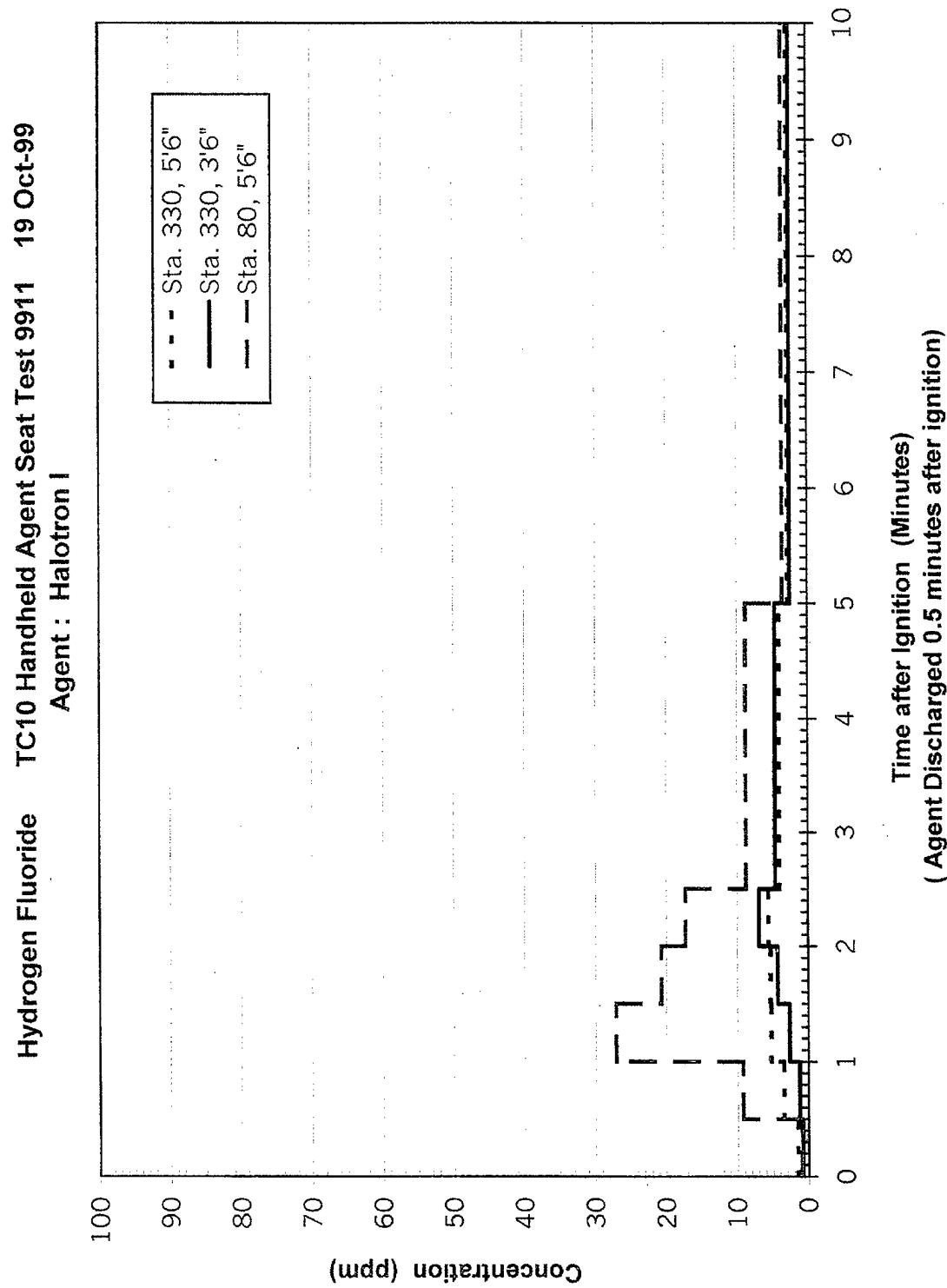
B.5 POWSUS ENVIROGEL WITH PHOSPHATE POWDER SAMPLE DATA.



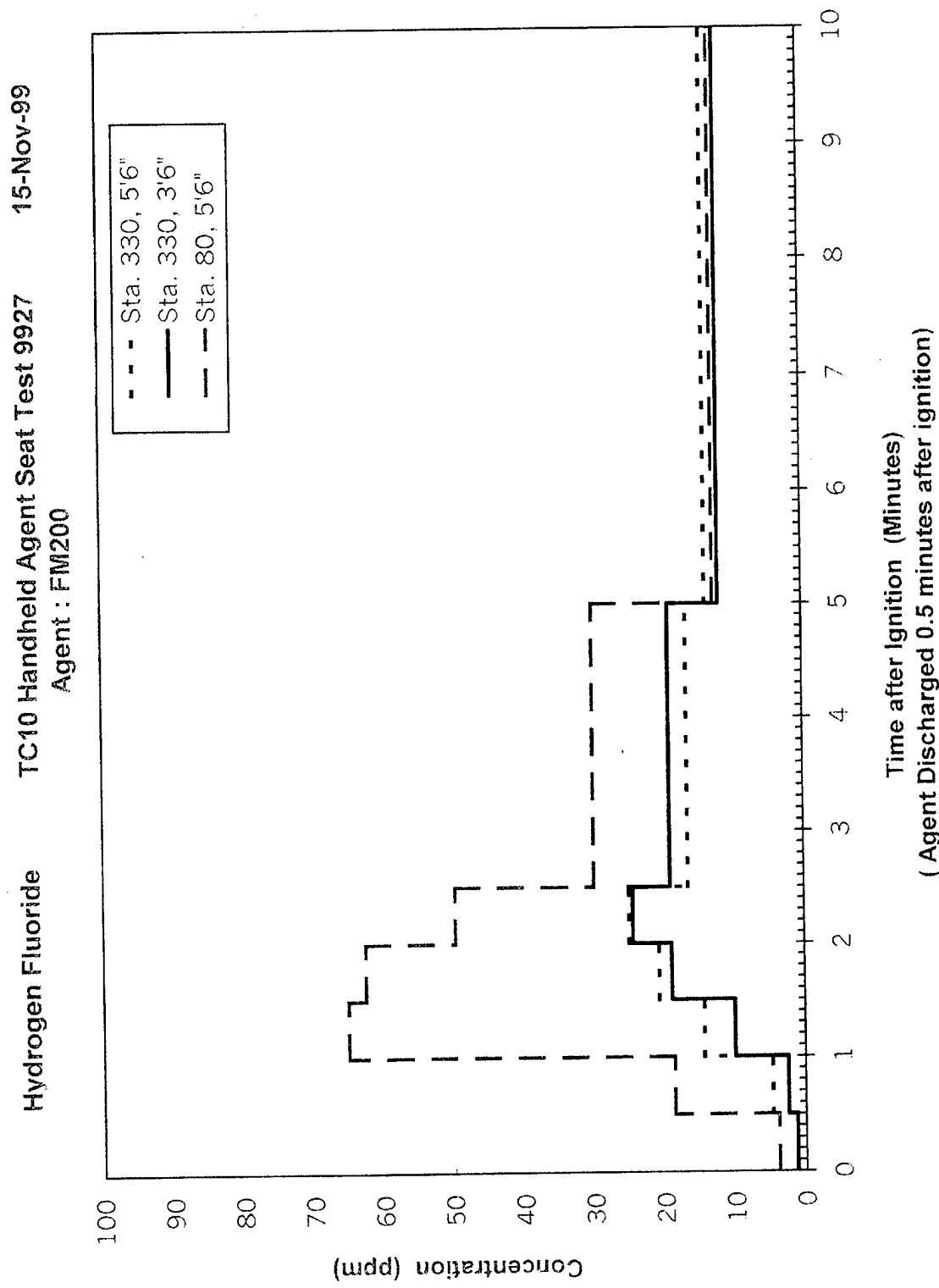
B.6 POWSUS ENVIROGEL WITH BICARBONATE POWDER SAMPLE DATA.



B.7 AMERICAN PACIFIC HALOTRON 1 SAMPLE DATA.



B.8 GREAT LAKES CHEMICAL FM-200 SAMPLE DATA.



B.9 NORTH AMERICAN FIRE GUARDIAN P IV SAMPLE DATA.

